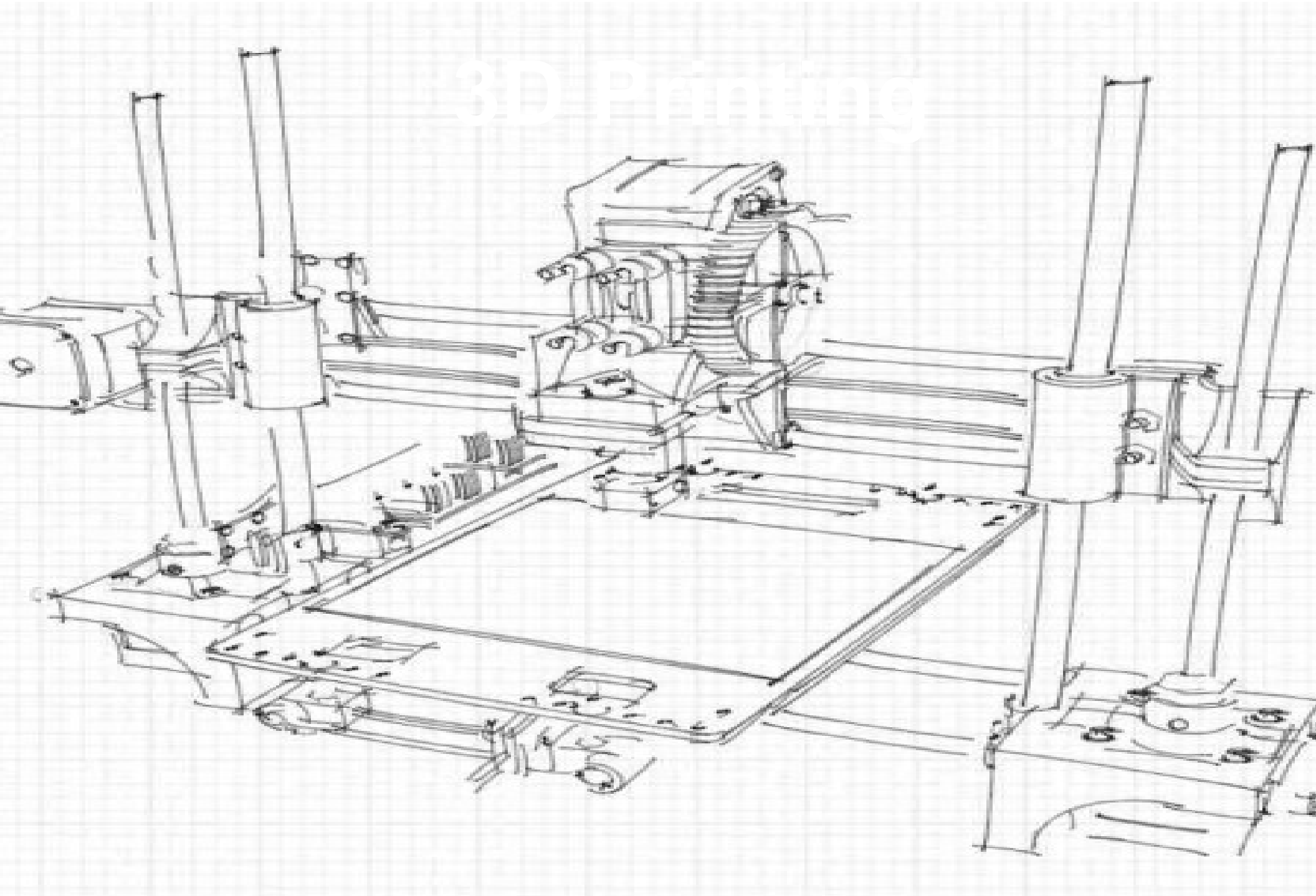

3D Printing

3D Printing

- What is it?
- When did it start?
- What are the methods?
- What machinery is required?
- What software is required?
- What is the process?
- How do I get started?

3D Printing – What is it?

- 3D Printing is a process for making a physical object from a three-dimensional digital model, typically by laying down many successive thin layers of a material. It brings a digital object, its Computer Aided Design (CAD) representation, into its physical form by adding material, layer by layer.

3D Printing – How it works

Start with a 3D CAD file either by creating the 3D model or scanned with a 3D scanner

Industrial Revolution(S)

1st - 18th & 19 century in America & Europe

- steam engine, iron, textiles

2nd - 1870 to 1914

- steel, oil, electricity, mass production

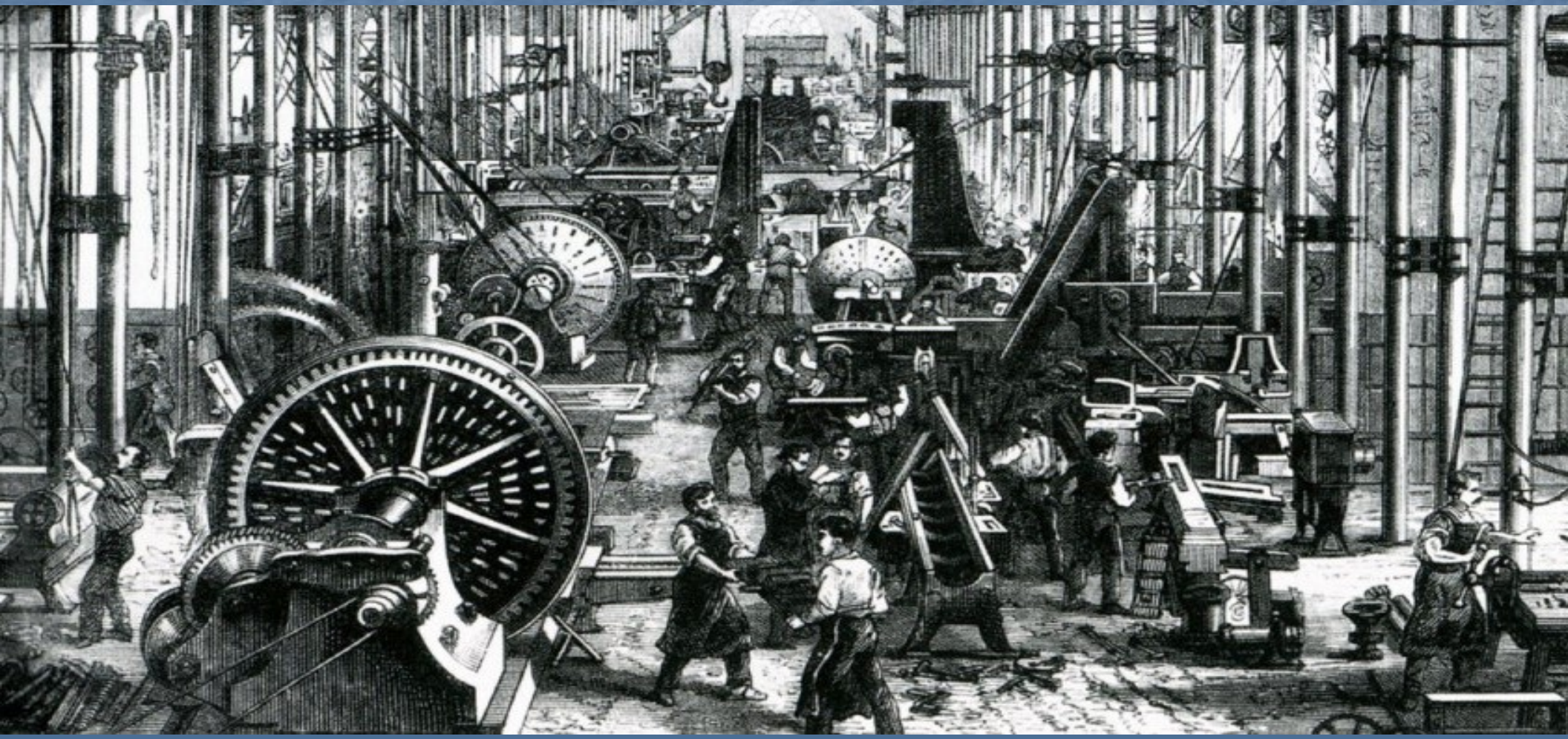
3rd - 1980's to present

- digital revolution, computers, internet, information technology

4th – Now

- builds on digital revolution, emerging technologies
- robotics, artificial intelligence, nanotechnology, quantum computing biotechnology, Internet of Things (IoT), 3D printing, autonomous vehicles

1800's Manufacturing



1940’ Manufacturing

Today's Manufacturing

3D Printing - Development

Combination of Emerging Technologies

- Computers & Electronics
  - Microprocessor (1971)
- Computer Numeric Control (CNC)
  - MIT Servomechanisms Lab (Early 1940's)
  - Stepper Motor (1960-1980)
- Computer Aided Design (CAD)
  - MIT – Sketchpad (Mid 1960's)
  - 3D (1970's)
  - Solid Modeling (1980's)

3D Printing – Key Events

- 1980 – First Patent Application
  - Dr. Kodama, Japan
- 1986 - Stereolithography Apparatus (SLA)
  - Charles Hull, 3D Systems Corporation
- 1989 - Selective Laser Sintering (SLS)
  - Carl Deckard, University of Texas
- 1992 - Fused Deposition Modelling (FDM)
  - Scott Crump, Stratasys Inc.
- 2007 – First system under $10,000
  - 3D Systems
  - RepRap - concept of an open source, self-replicating 3D printer
- 2009 – First Kit Printer
  - Based on RepRap concept

3D Printing Matures

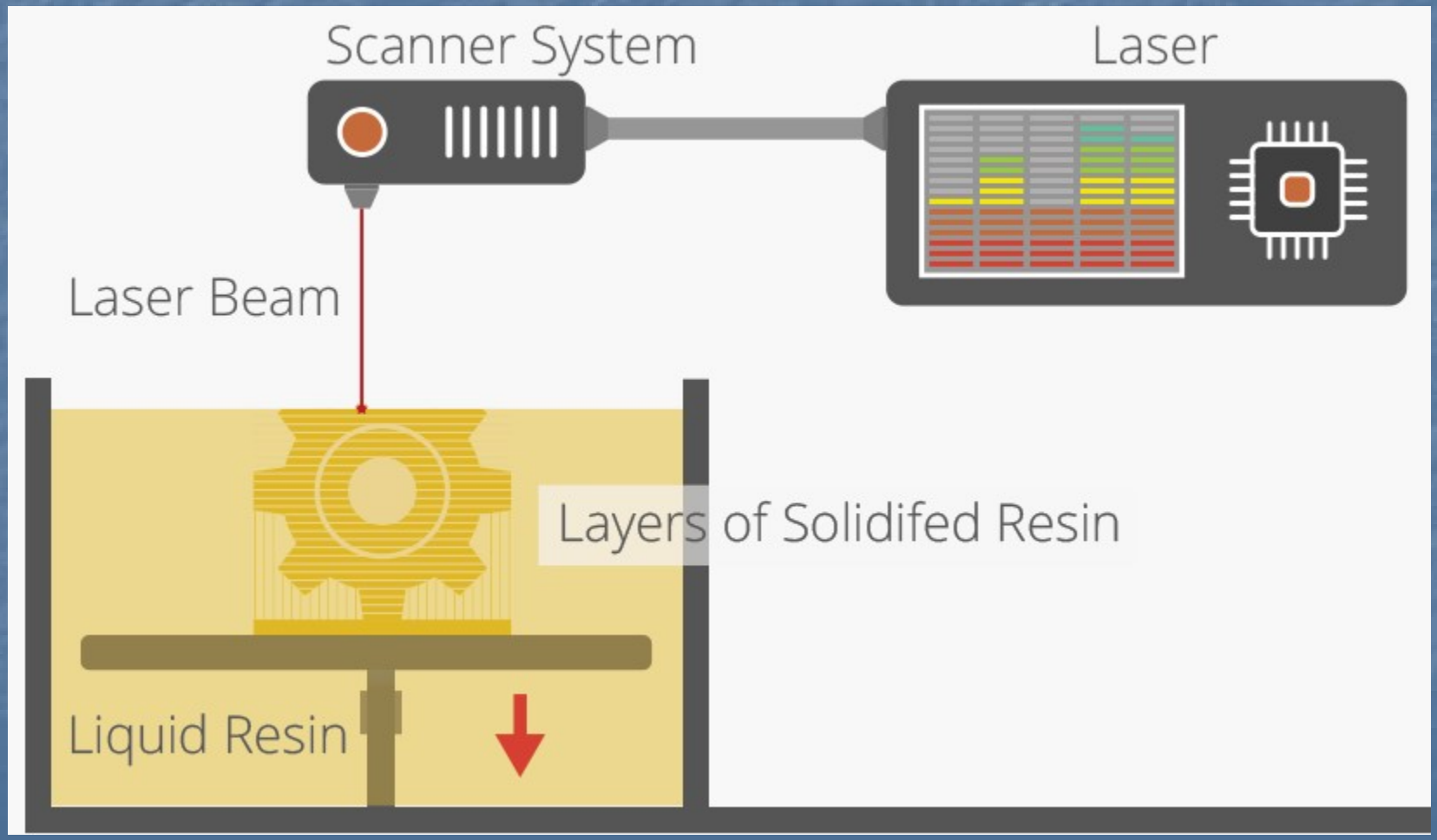
- The cost of 3D printers has plummeted
- The accuracy of 3D printing has improved and continue to get better
- The machines are user-friendly (anyone can use them)
- It's easier to design 3D models thanks to free software programs
- Innovators continue to push the envelope, keeping things fresh and exciting

3D Printing

- Industrial Applications
  - Rapid Prototyping
  - Specialized Production
  - Large & Expensive Machines
- Medical
  - Organ Reproduction
  - Prosthetics
- Personal Use
  - Lowest Cost
  - Open Source Designs
  - Kits - Easy to build
  - Ideal for the hobbyist

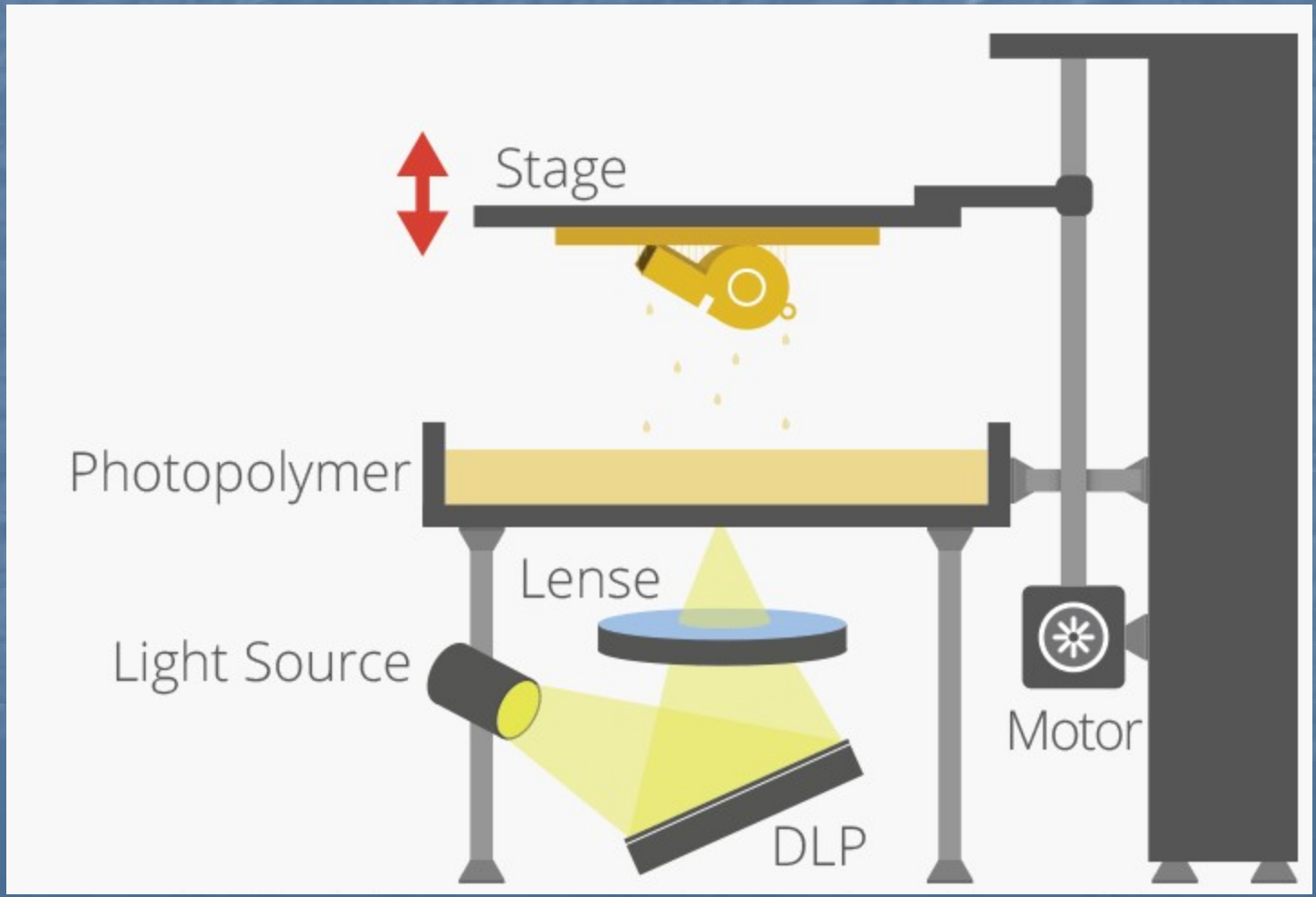
3D Printing – Processes

Stereolithography



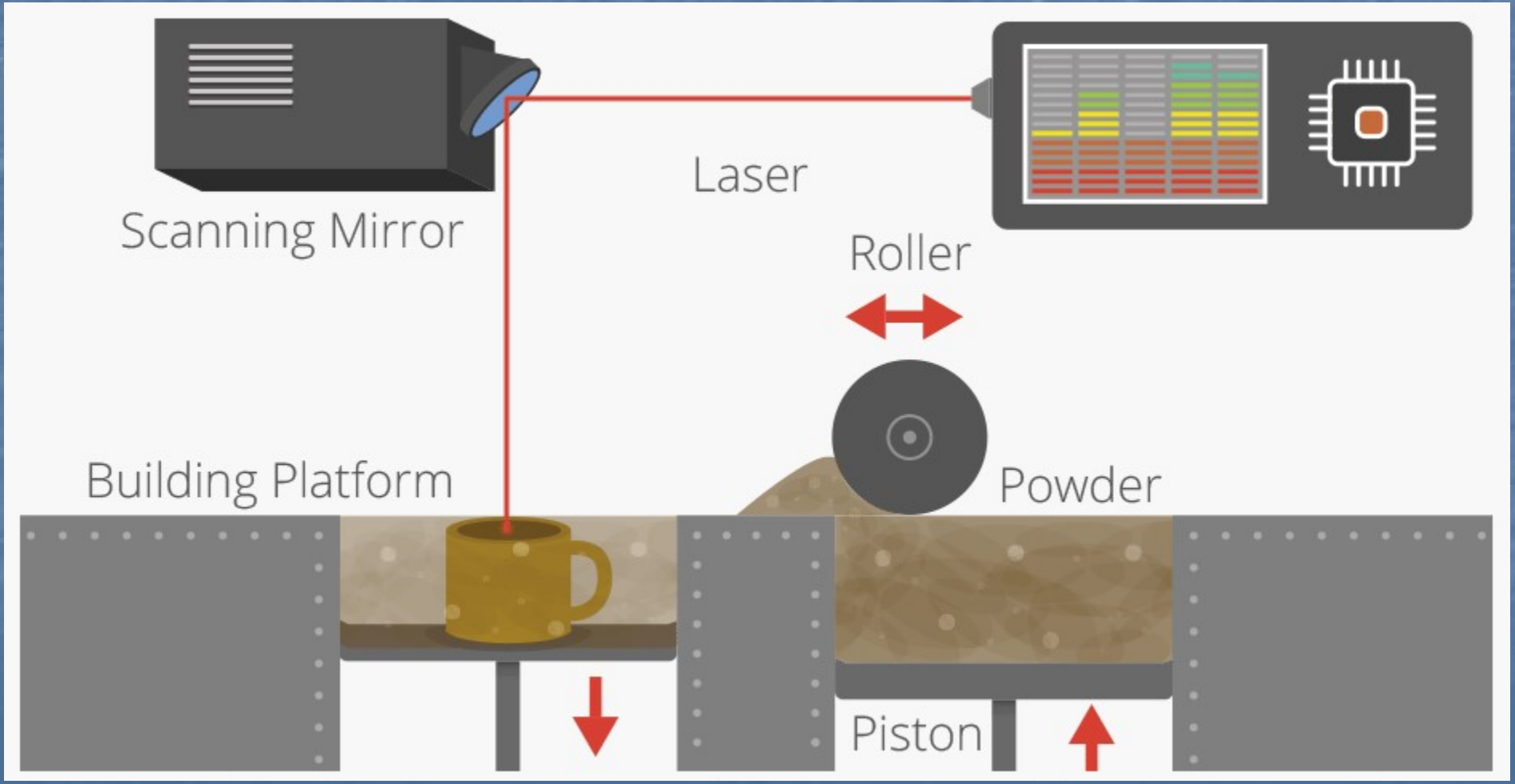
3D Printing – Processes

Digital Light Processing (DLP)



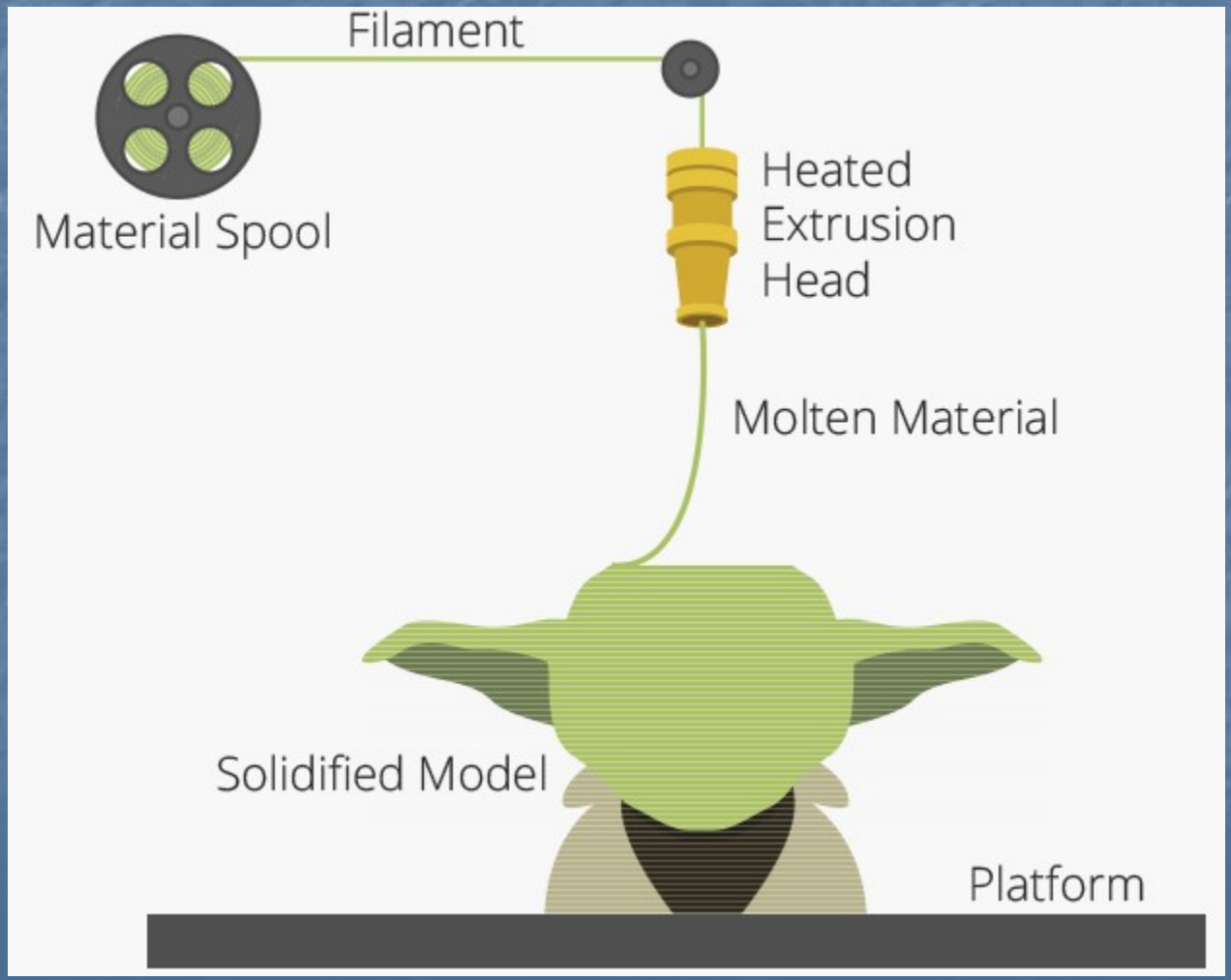
3D Printing – Processes

Laser Sintering/Laser Melting



3D Printing – Processes

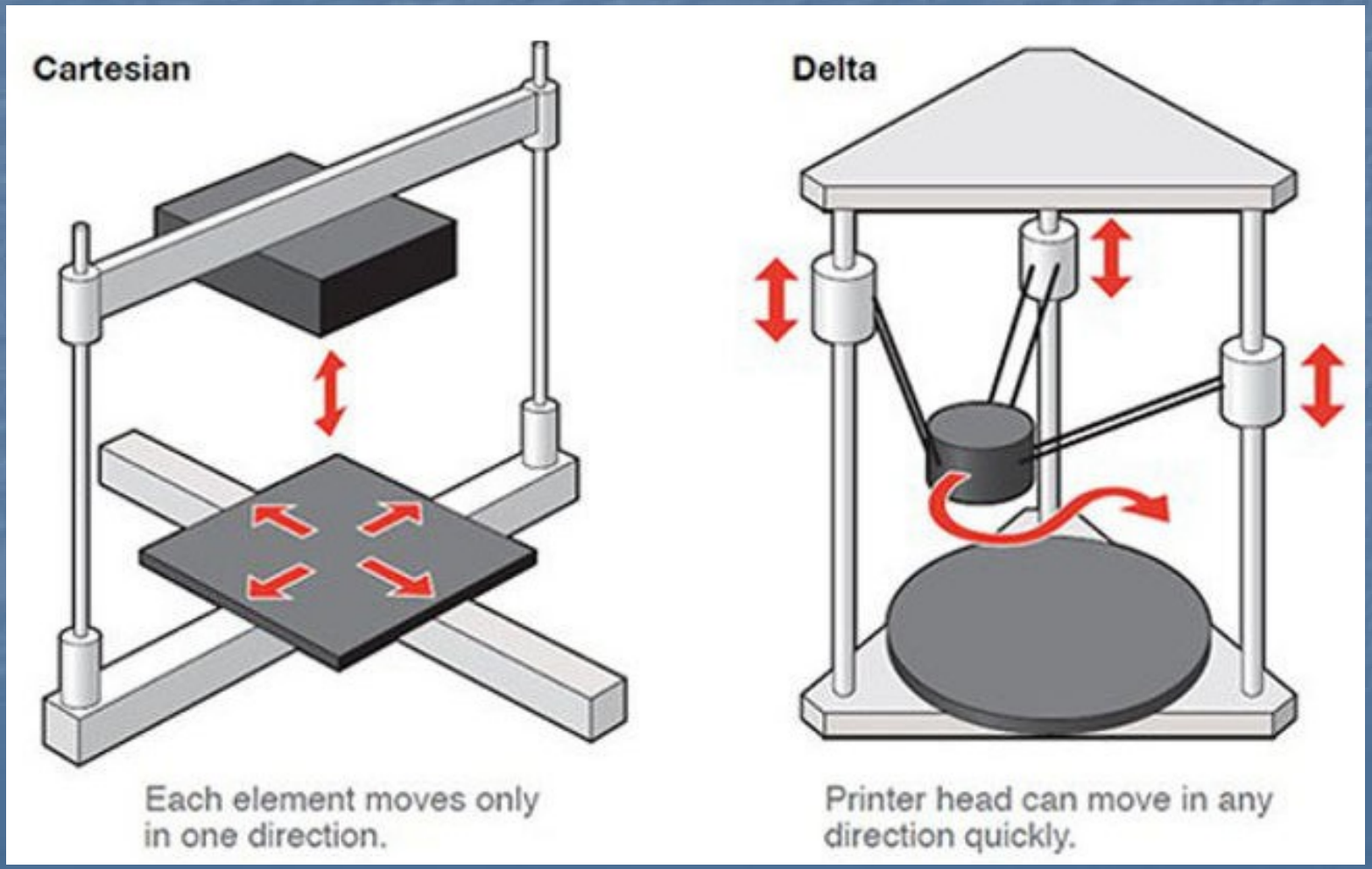
Fused Deposition Modelling (FDM)



3D Printing – Materials

- Plastics
  - ABS
  - PLA
  - PETG
  - Carbon Fiber
- Metals
  - Aluminium & Cobalt derivatives
  - Stainless Steel
  - Gold & Silver
- Ceramics
  - Requires Firing & Glazing
- Paper
- Bio Materials
  - Replacement Body Parts
- Food
  - Sugar & Chocolate
  - Pasta & Meat
- Concrete
  - Home Construction
- Other

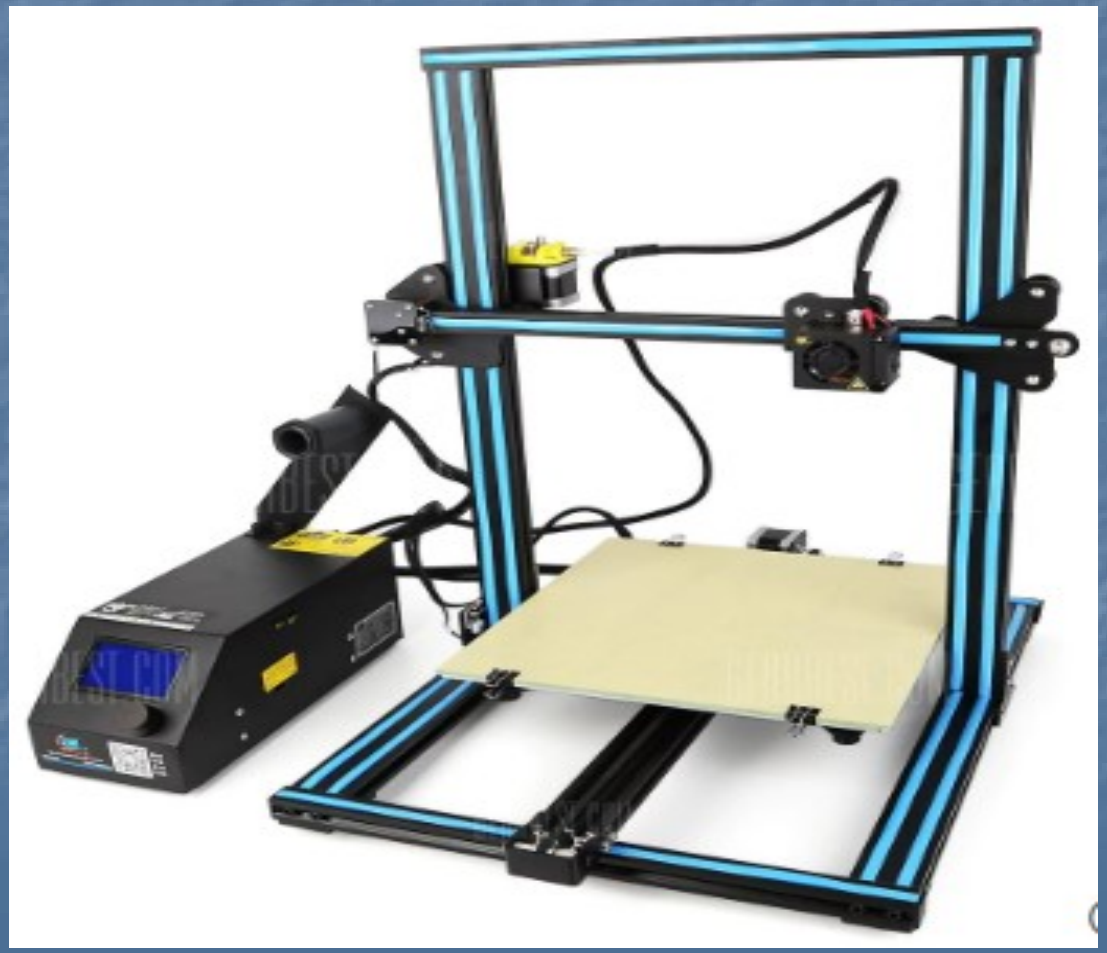
3D Printing Machines
Motion Types



3D Printing Machines (FDM)

Cartesian

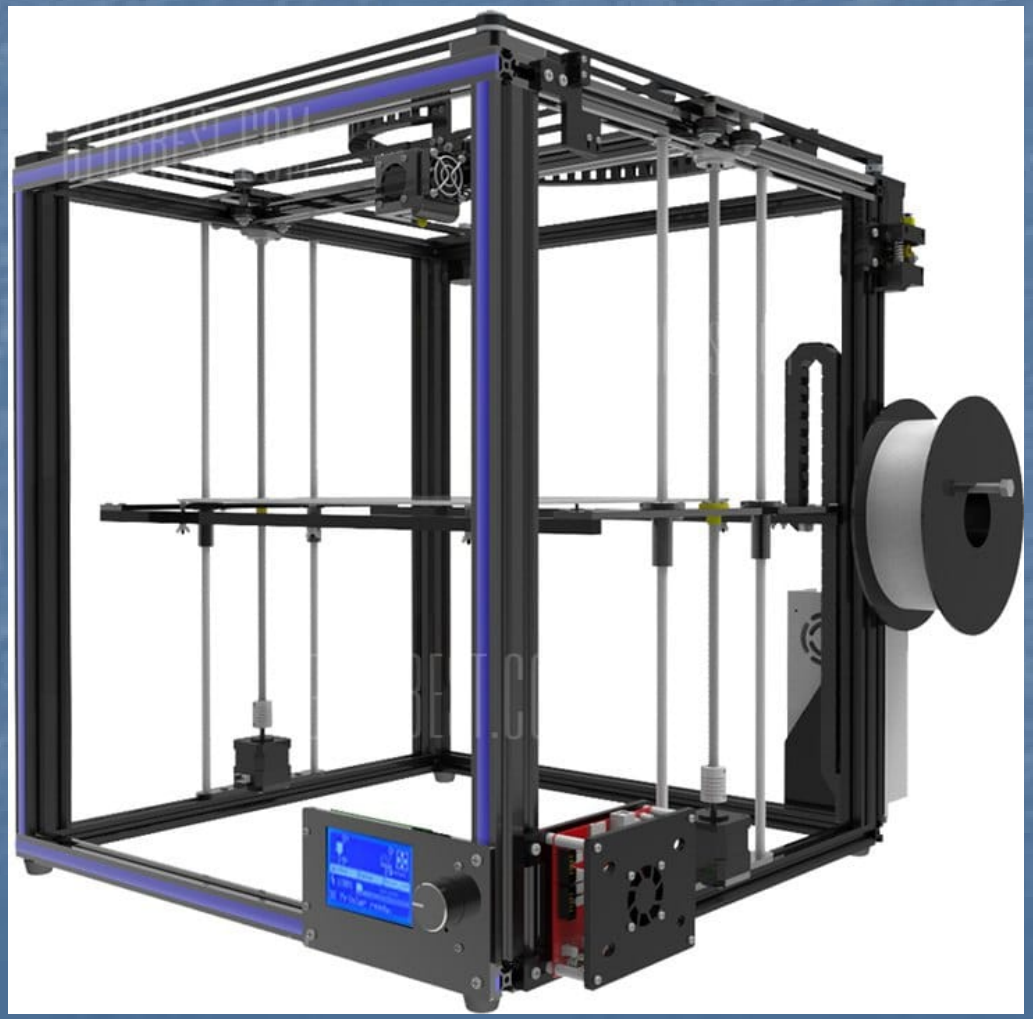
- X, Y, Z
- Simple Design
- Lowest Cost



3D Printing Machines (FDM)

Core XY

- XY, Z
- Cartesian Variation
- Increased Complexity
- Increased Cost



3D Printing Machines (FDM)

- Rostock
- Kossel
- Delta
  - A, B, C
  - X, Y, Z
- Increased Complexity
- Increased Cost
- Improved Quality

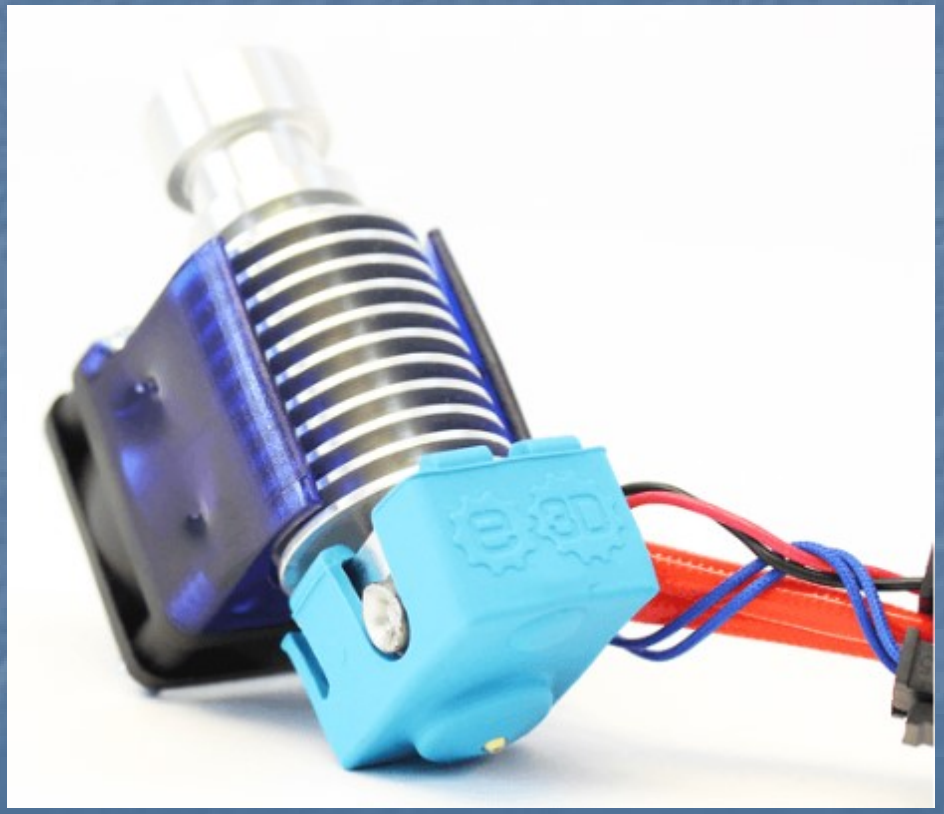
3D Printer - Components

- Motion
  - Stepper Motor
  - Drive
    - Timing Belt
    - Lead Screw
  - Carriage
    - Linear Bearing
      - Linear Guide or Shaft
    - Wheels & Bearings

3D Printer - Components

Extrusion

- Filament Feed
  - Stepper Motor
  - Extruder Drive Gear
- HotEnd
  - Heater
    - 250°C (480°F)
  - Thermistor
  - Nozzle
    - .2 - .7mm



3D Printer - Components

- HeatBed
  - Printed Circuit Board
  - Aluminum Plate with Heater
    - 100 – 500 Watts
    - 100°C (212°F)
  - Thermistor
- Print Surface
  - Usually Glass
  - Adhesion

3D Printer - Components

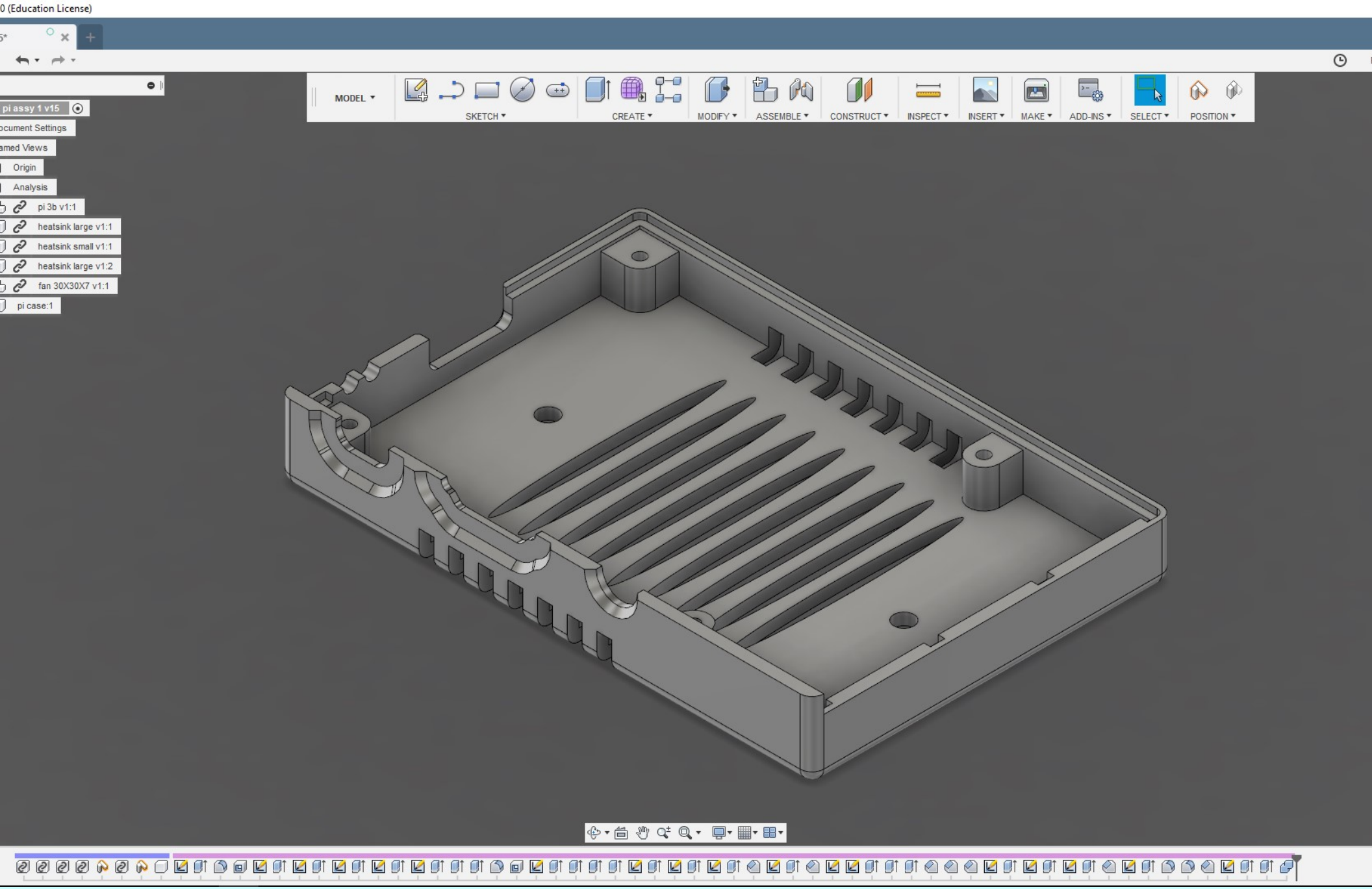
- Electronics
  - Power Supply
    - Stepper Motors
    - HotEnd
    - HeatBed
      - Higher wattage uses AC line
  - Controller
    - User Interface
      - Display, Touch Screen, USB, Wifi
    - Motor Drive
      - Limit Switches
    - Temperature Control

3D Printing – Making it Work!

- Computer Aided Design (CAD)
  - Create 3 dimensional virtual model
- Slicer
  - Slices virtual model into layers
  - Creates machine control file
- Printing Material
  - Wide array of plastics
    - Some include metal, wood or carbon fiber
- 3D Printer
- Learn to speak metric

Computer Aided Design (CAD)

- Free Software
  - Sketchup
  - FreeCad
  - Tinkercad
  - Blender
  - Fusion 360
    - Parametric Modeling
  - OpenSCad
    - Parametric Modeling
    - Programming Language
  - Many more
- Create .stl (Stereolithography) file


0 (Education License)
MODEL
SKETCH
CREATE
MODIFY
ASSEMBLE
CONSTRUCT
INSPECT
INSERT
MAKE
ADD-INS
SELECT
POSITION
pi assy 1 v15
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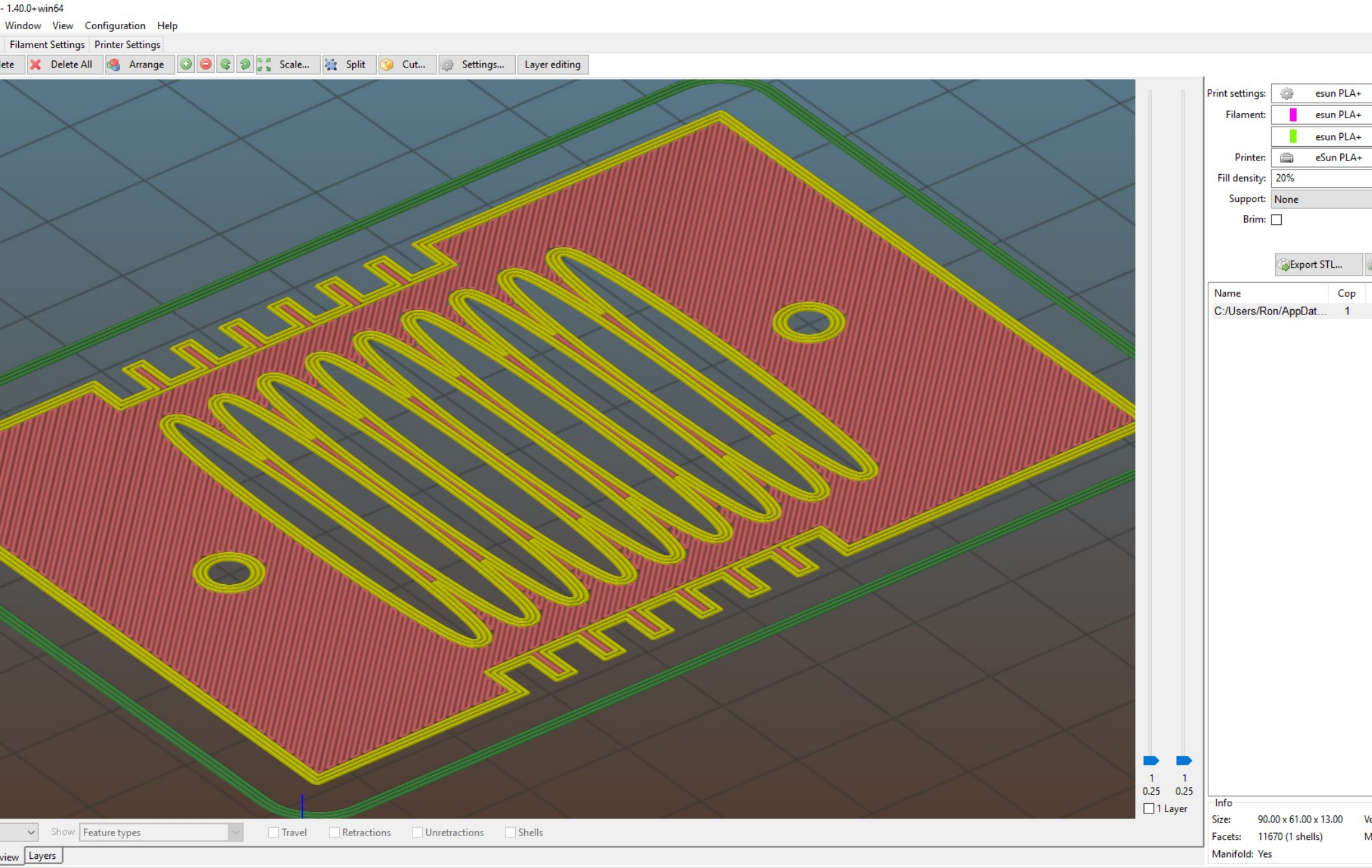
amed Views
Origin
Analysis
pi 3b v1:1
heatsink large v1:1
heatsink small v1:1
heatsink large v1:2
fan 30X30X7 v1:1
pi case:1

Slicer

- Recreates model from .stl file
- Cuts model into layers
  - Hundreds of variables
    - Print - Layer parameters & Speed
    - Material - Size, Temperature, Cooling
    - Printer - Type, Size, Extruder, Firmware
- Generate .gcode file
- Free Software
  - Slic3r
  - Cura
  - Others


- 1.40.0+win64
Window View Configuration Help
Filament Settings Printer Settings
Delete All Arrange Scale... Split Cut... Settings... Layer editing
Print settings: esun PLA+
Filament: esun PLA+
esun PLA+
Printer: eSun PLA+
Fill density: 20%
Support: None
Brim:
Export STL...
Name Cop
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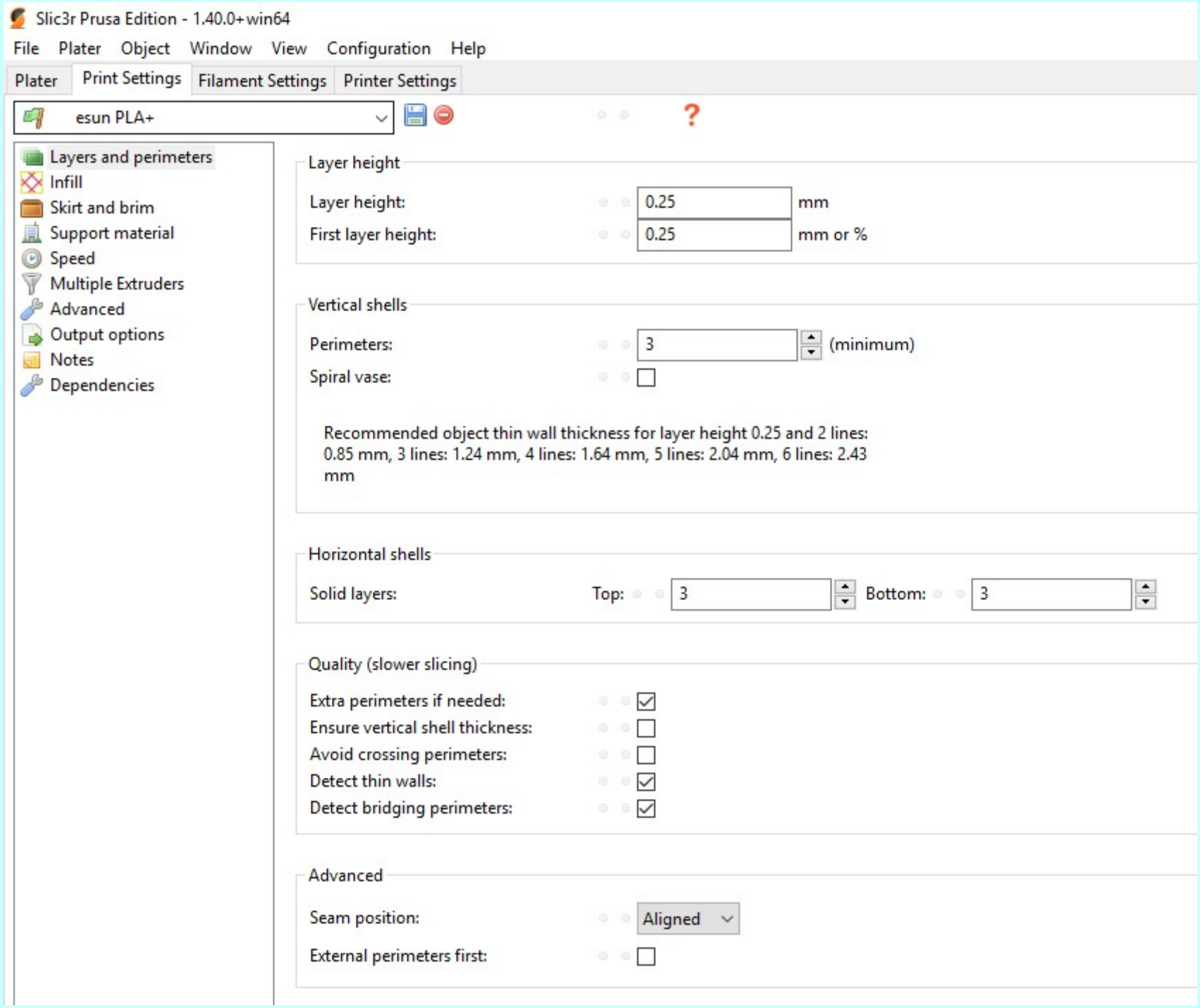
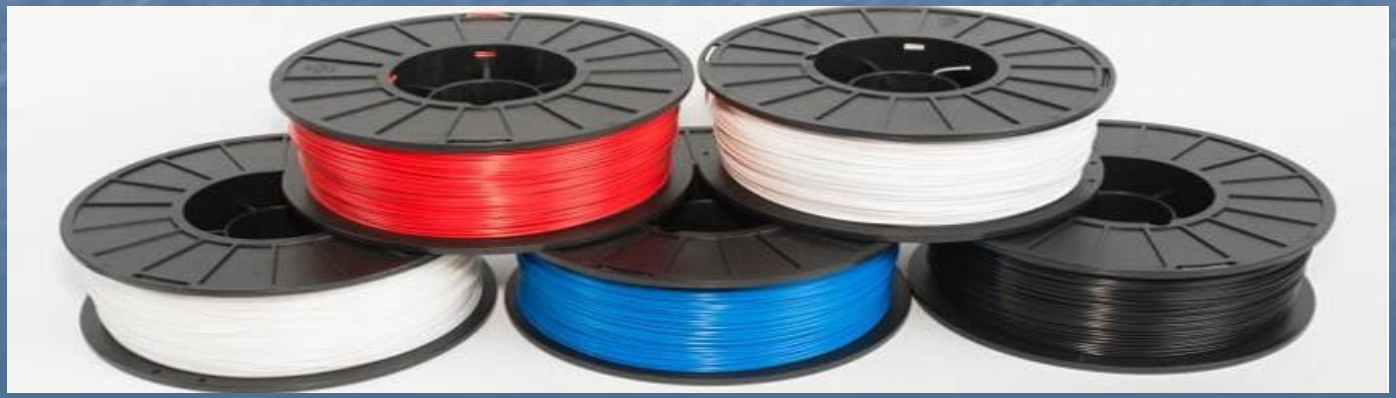
1 1
0.25 0.25
1 Layer
Info
Size: 90.00 x 61.00 x 13.00
Facets: 11670 (1 shells)
Manifold: Yes
Show Feature types
Travel Retractions Unretractions Shells
Layers


Slic3r Prusa Edition - 1.40.0+win64
File Plater Object Window View Configuration Help
Plater Print Settings Filament Settings Printer Settings
esun PLA+
Layers and perimeters
Infill
Skirt and brim
Support material
Speed
Multiple Extruders
Advanced
Output options
Notes
Dependencies
Layer height
Layer height: 0.25 mm
First layer height: 0.25 mm or %
Vertical shells
Perimeters: 3 (minimum)
Spiral vase:
Recommended object thin wall thickness for layer height 0.25 and 2 lines: 0.85 mm, 3 lines: 1.24 mm, 4 lines: 1.64 mm, 5 lines: 2.04 mm, 6 lines: 2.43 mm
Horizontal shells
Solid layers: Top: 3 Bottom: 3
Quality (slower slicing)
Extra perimeters if needed:
Ensure vertical shell thickness:
Avoid crossing perimeters:
Detect thin walls:
Detect bridging perimeters:
Advanced
Seam position: Aligned
External perimeters first:

```
; generated by Slic3r Prusa Edition 1.40.0+win64 on 2018-07-14 at 10:15:45

;

; external perimeters extrusion width = 0.50mm
; perimeters extrusion width = 0.50mm
; infill extrusion width = 0.50mm
; solid infill extrusion width = 0.50mm
; top infill extrusion width = 0.50mm

M107
M190 S65 ; set bed temperature and wait for it to be reached
M104 S215 ; set temperature
G28 ; home all axes
G1 Z5 F5000 ; lift nozzle
M117 "Printing..."
; Filament gcode
M109 S215 ; set temperature and wait for it to be reached
G21 ; set units to millimeters
G90 ; use absolute coordinates
M82 ; use absolute distances for extrusion
G92 E0
G1 E-0.80000 F1800.00000
G92 E0
G1 Z0.250 F9000.000
G1 X54.962 Y17.032
G1 E0.80000 F1800.00000
G1 X55.365 Y15.897 E0.86062
G1 X56.123 Y14.672 E0.93310
G1 X57.050 Y13.764 E0.99846
G1 X57.874 Y13.220 E1.04815
G1 X58.663 Y12.864 E1.09170
G1 X59.530 Y12.632 E1.13691
G1 X60.555 Y12.528 E1.18874
G1 X146.713 Y12.529 E5.52591
G1 X147.470 Y12.594 E5.56414
G1 X148.507 Y12.831 E5.61766
G1 X149.454 Y13.262 E5.67006
```

3D Printing - Materials

- Types
  - PLA, ABS, PETG, Flex and more
  - Hybrid - Wood, Metal, Carbon Fiber
  - Water Soluble
- Colors
  - Opaque
  - Translucent

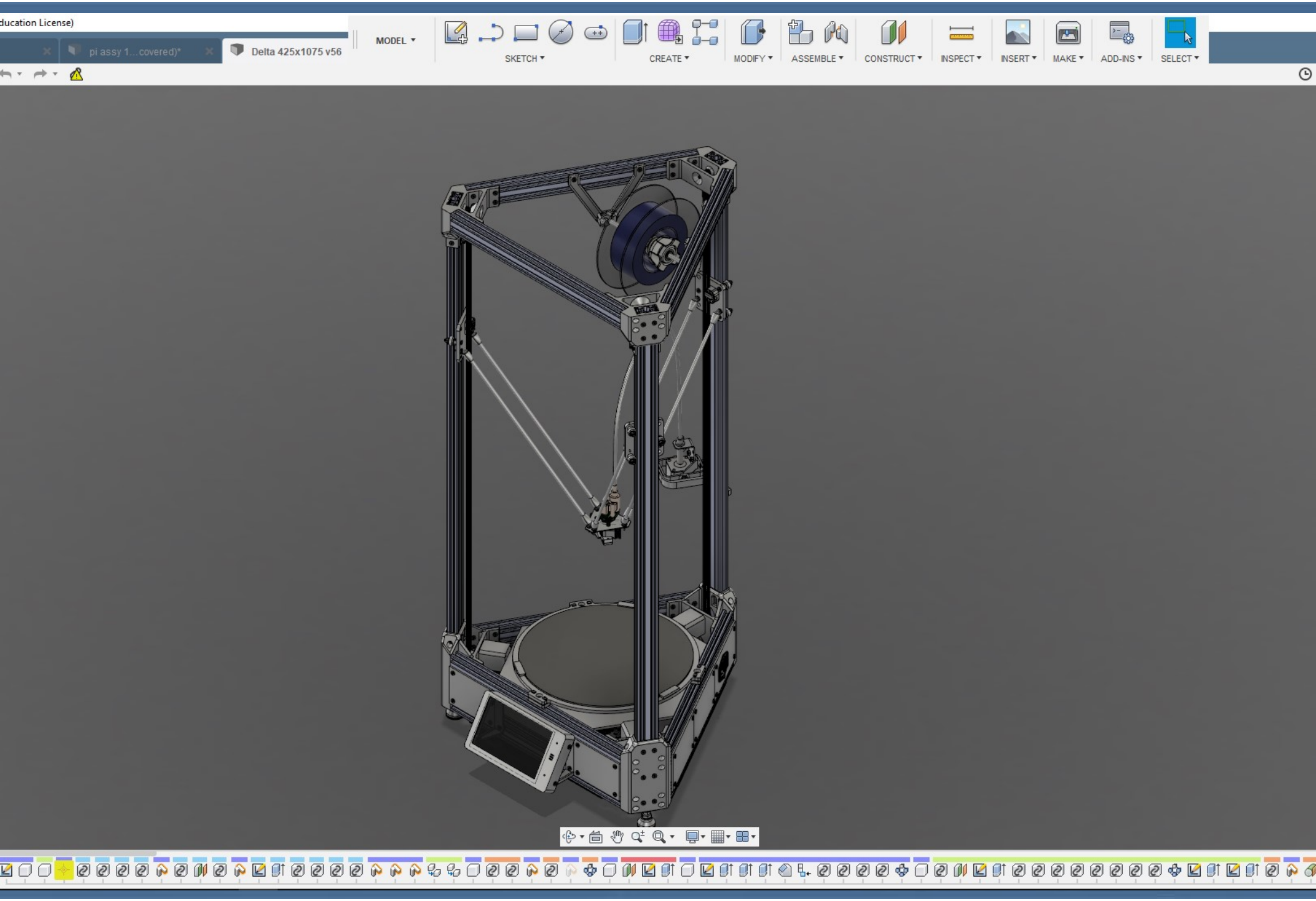


Let’s print something

My Printer

Delta

- Print volume: 300mm dia. X 400mm high
- Accuracy
  - Precise motor control
  - Zero backlash
  - Minimize moving mass
- Fast
  - Can print at 150mm/sec (quality suffers as speed increases)
  - Preheat: ambient to print temperatures in 2 ½ min.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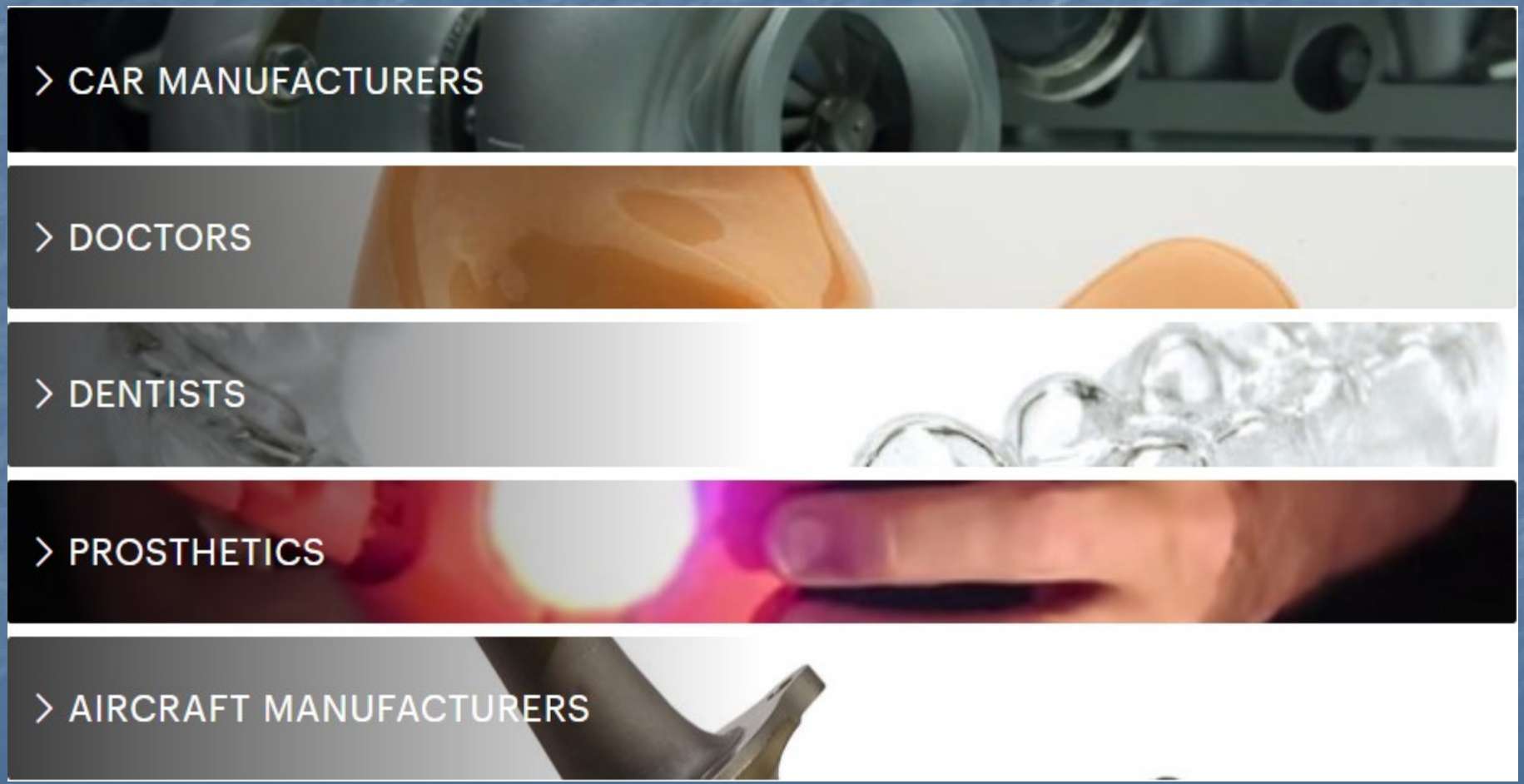
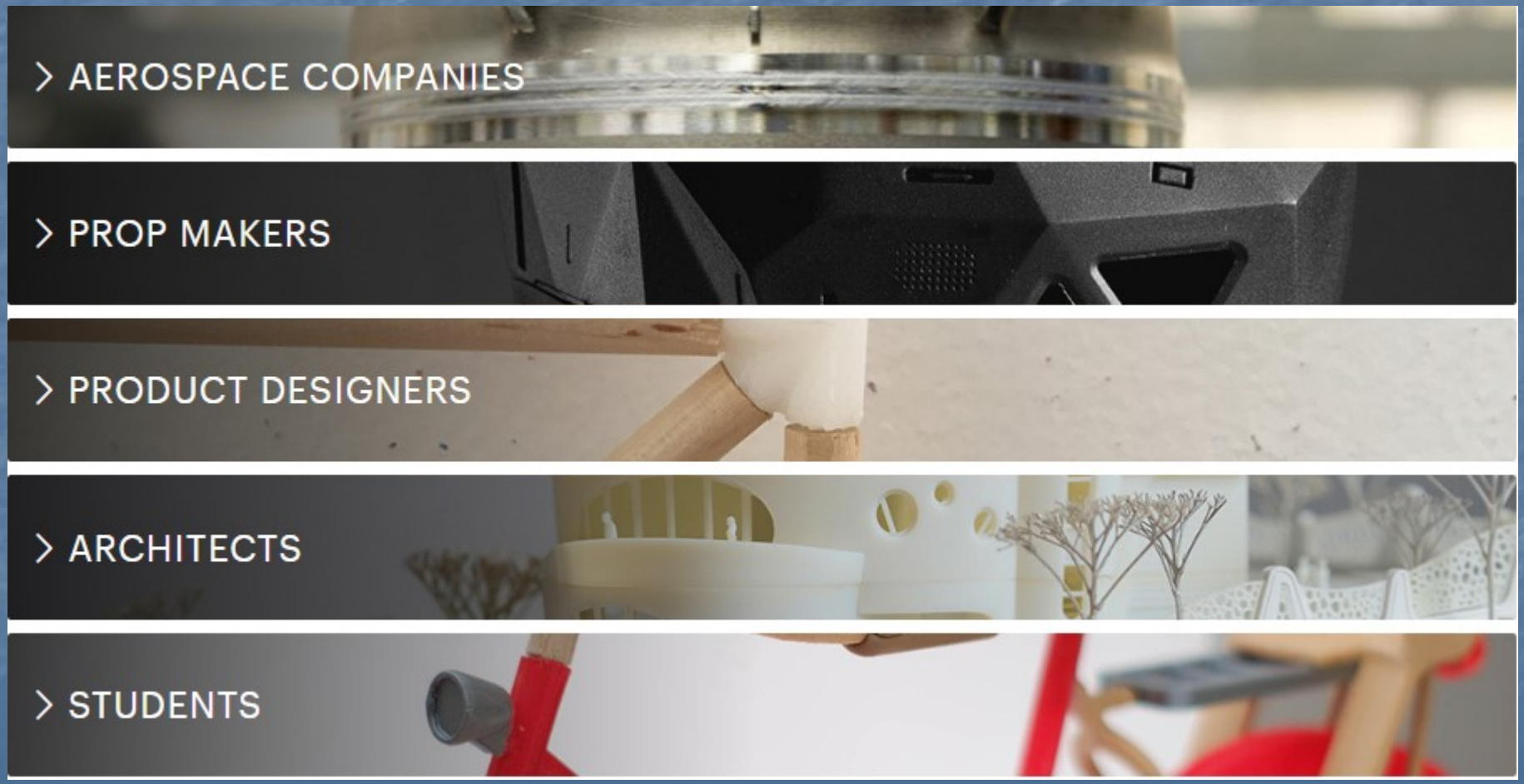
pi assy 1...covered)*
Delta 425x1075 v56
MODEL
SKETCH
CREATE
MODIFY
ASSEMBLE
CONSTRUCT
INSPECT
INSERT
MAKE
ADD-INS
SELECT

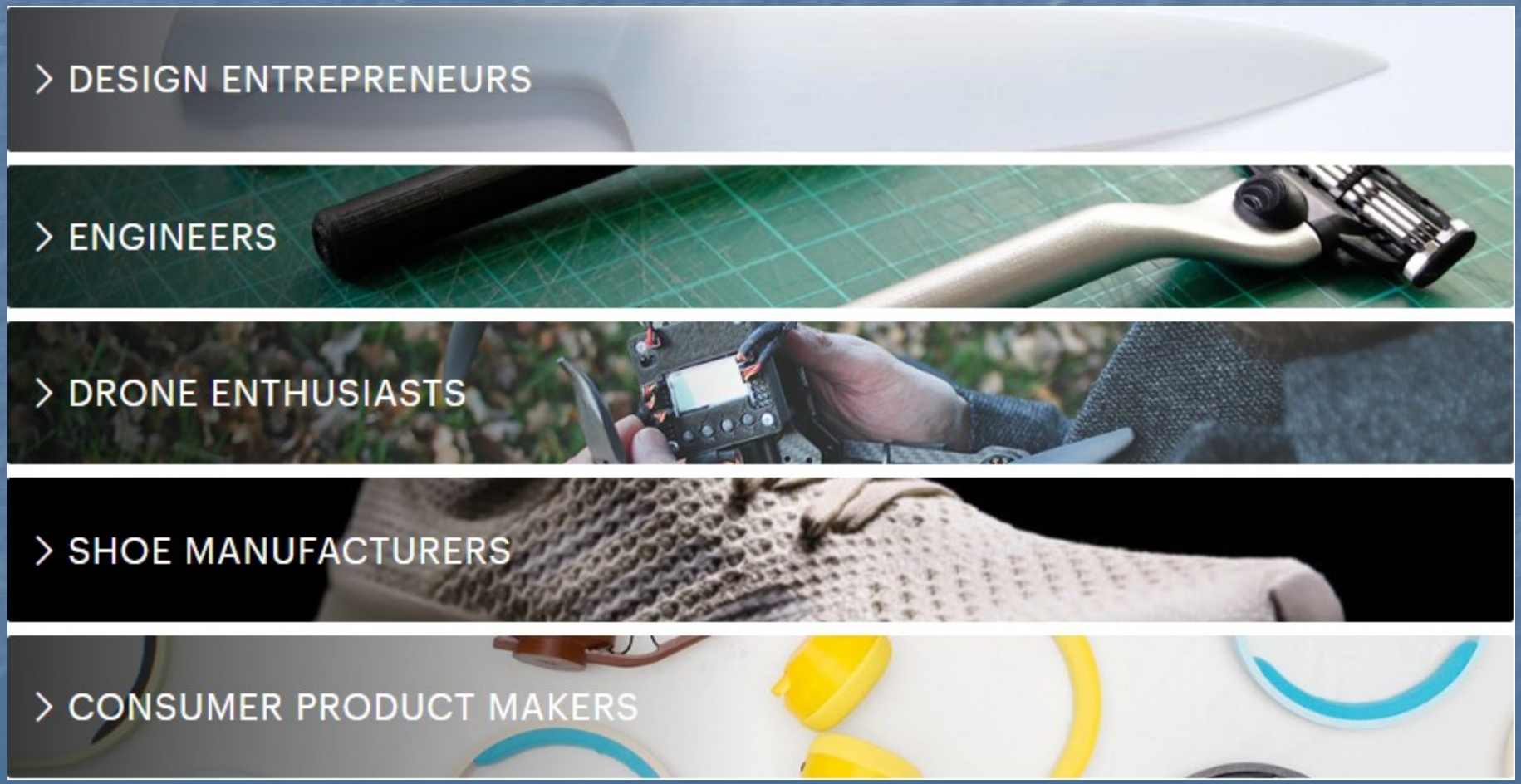
Who is using 3D printing?



Who is using 3D printing?



Who is using 3D printing?



3D Printing - How to get started

Research
- Read and study
- What do you want to do?

Choose a printer
- Materials
- Purchase or build your own?
- Budget

Fine tuning
- Experimentation

3D Printing Resources

reprap.org

3dprinting.com

3dprintingindustry.com

openbuilds.com

grabcad.com

youtube.com

google.com

amazon.com

- thingiverse.com
- youmagine.com
- cults3d.com